

WIDE-FIELD IMAGING INTERFEROMETRY TESTBED

DEVELOPING A POWERFUL TECHNIQUE FOR FUTURE SPACEBORNE INTERFEROMETERS



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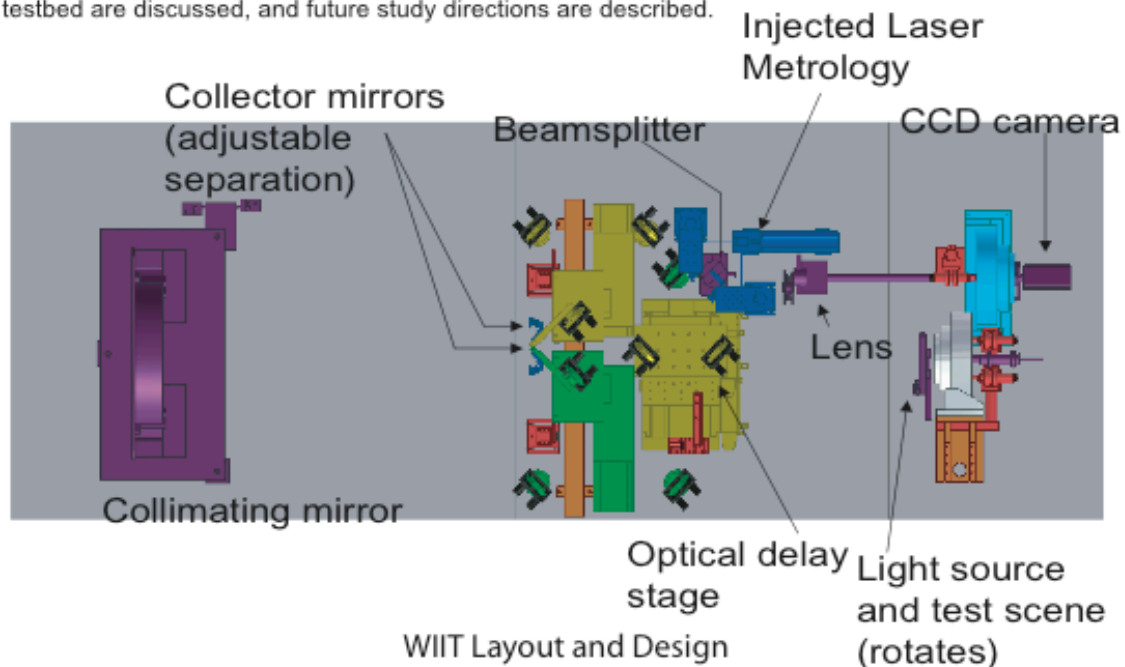
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Abstract:

We present recent results from the Wide-Field Imaging Interferometry Testbed (WIIT). Using a multi-pixel detector for spatial multiplexing, WIIT has demonstrated the ability to acquire wide-field imaging interferometry data. Specifically, these are "double Fourier" data that cover a field of view much larger than the subaperture diffraction spot size. This ability is of great import for a number of proposed missions, including the Space Infrared Interferometric Telescope (SPIRIT), the Submillimeter Probe of the Evolution of Cosmic Structure (SPECS), and the Terrestrial Planet Finder (TPF-I)/Darwin. The recent results are discussed and analyzed, the characteristics and behavior of the testbed are discussed, and future study directions are described.



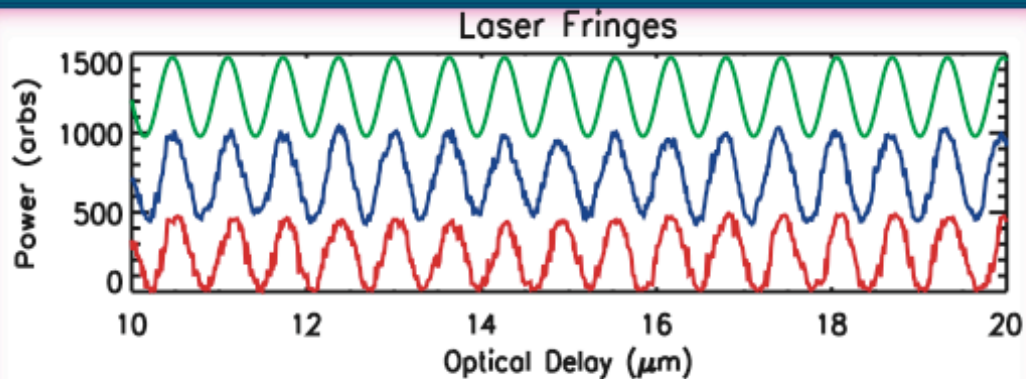
The figure at left shows a top view of WIIT, the Wide-field Imaging Interferometry Testbed, generated from a 3-D solid body model. Light from the source illuminates the collimator, which returns a collimated beam to the two collector mirrors. One of the collectors conveys a beam to the fixed arm, consisting entirely of stationary flat mirrors. The other sends light through the delay arm, consisting of two stationary flat mirrors and two mirrors mounted in a rooftop configuration on the delay line stage to provide optical delay. The beams from the two arms are combined at the beamsplitter and are focused by a single achromatic lens on the camera, which Nyquist samples the primary beam. A displacement measurement interferometer provides real-time metrology data.

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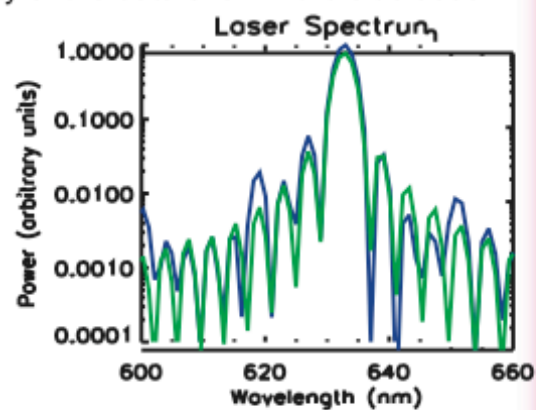
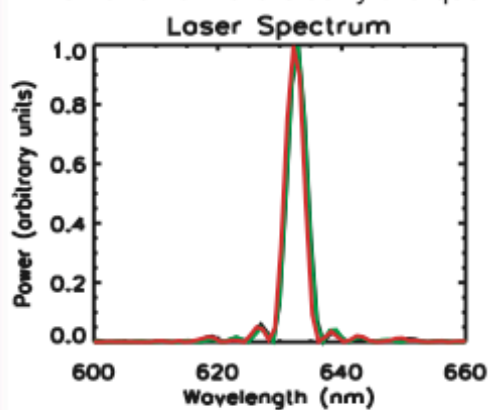
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Laser Fringes: In order to assess quality of data produced by the testbed, we use a laser-illuminated source. The figure above shows laser fringes acquired with WIIT. The three separate curves show a single data set (red), the coaddition of 3 data sets (blue), and a simple model (green). The data have shown high repeatability. Below, we show two figures of the Fourier Transform spectrum of a single data set (red), the coaddition of three datasets (blue), and theoretically perfect fringes (green). The figure on the left shows this plot on a linear scale, and demonstrates the high quality match of the data to the theoretical curve. This similarity is emphasized further in the log plot shown on the right, which shows more clearly the quality of the data even in the sidelobes.



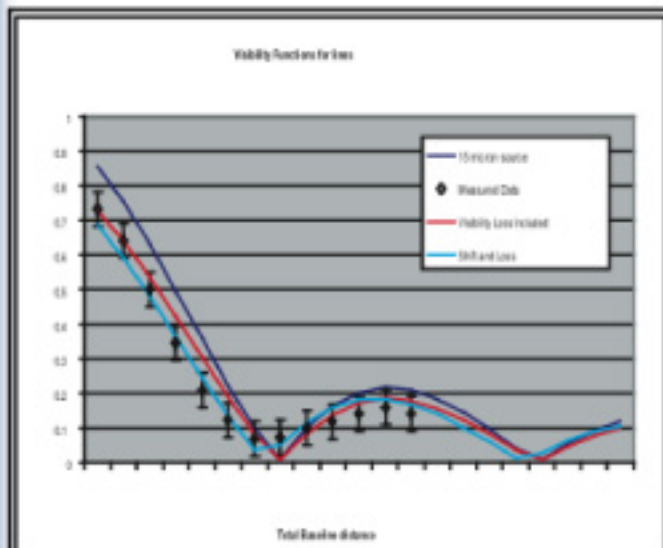
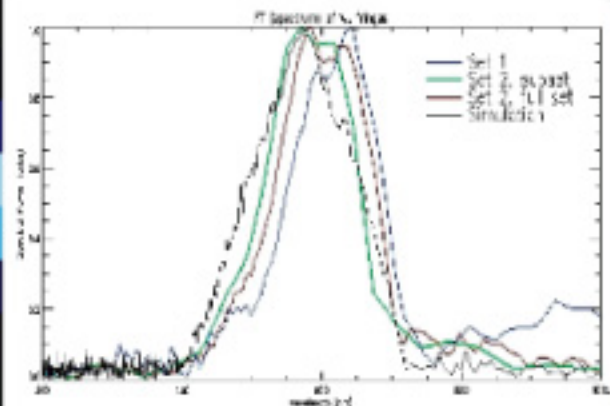
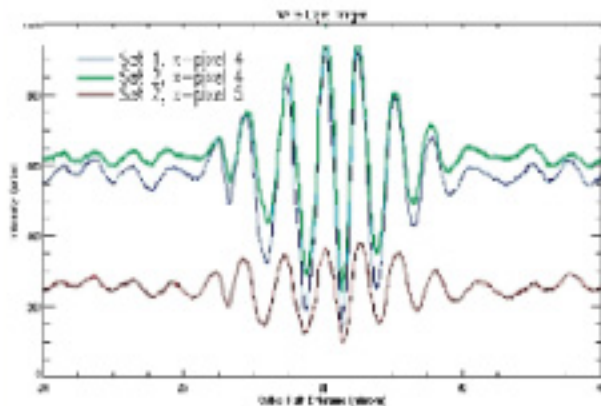
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White Light Fringes



These figures show white light fringes (above left), the distribution of light on the detector (above center), the Fourier transform spectrum of these white light fringes (above right), and the measured visibility function of the source (a 1.4 arcsec wide line). The fringes show the consistency of the fringe pattern from different days (green and blue lines) and from pixels at both the center of the point spread function and in the wing thereof. The spectrum shows that multiple data sets produce similar spectra, and with more careful data reduction it should be possible to calibrate the data and improve upon this result. The visibility plot demonstrates that the visibility function is in accord with predictions. This is the key element required for 1-D spatial image reconstruction.

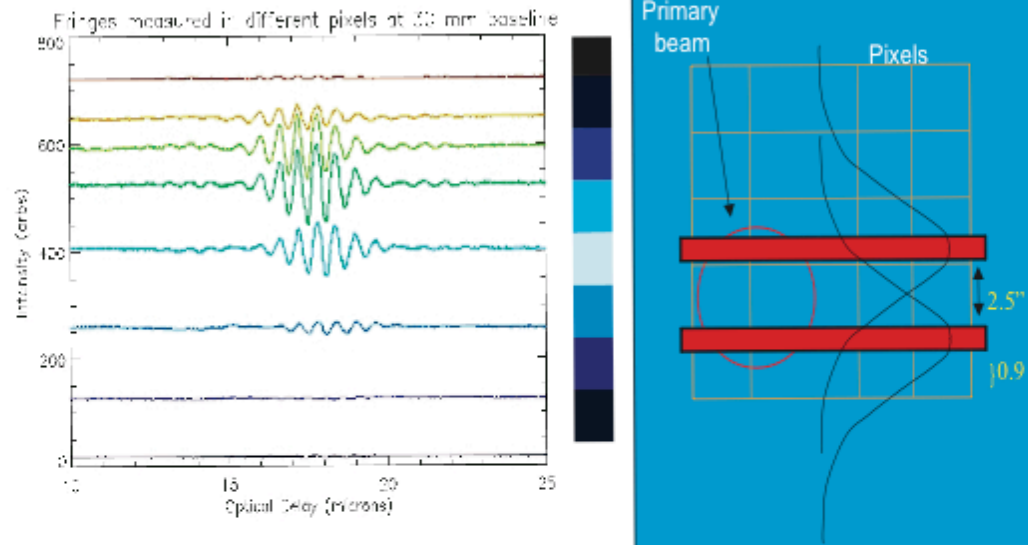
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Demonstration of Wide Field of View



This series of figures shows the basic principle behind wide field-of-view interferometry. Above right is a schematic drawing of the source used, consisting of two 10 micron wide lines (0.9 arcsec) separated by 30 microns (2.5 arcsec). In the center, above, the distribution of light across the detector is shown, and at left are the interferograms produced in each of these eight pixels. At the right are two columns of interferograms for such a source; those on the left are simulated interferograms for the two separated sources (blue and green) and the interferogram predicted for a pixel where the light from the sources overlaps (red). On the right are interferograms acquired using WIIT, which show similar behavior. The figures show clearly the two major effects due to increasing baseline. The visibility function of individual interferograms modulates with baseline, and the relative location of zero path difference (ZPD) for the two interferograms shift; the interferograms separate with increasing baseline.

References:

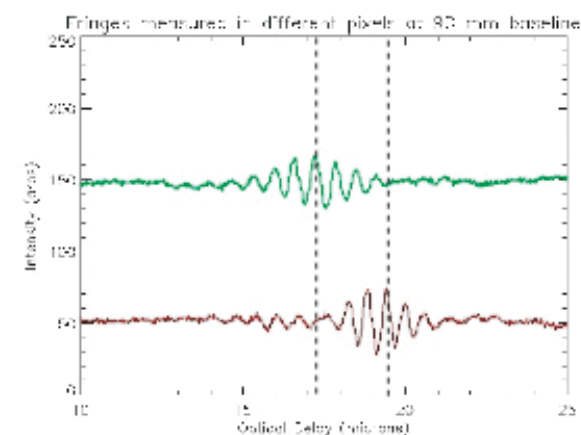
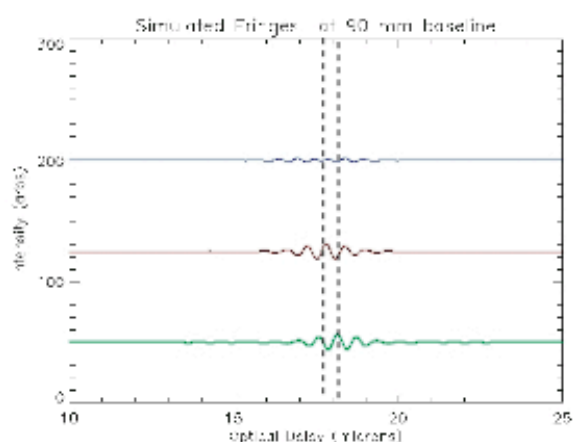
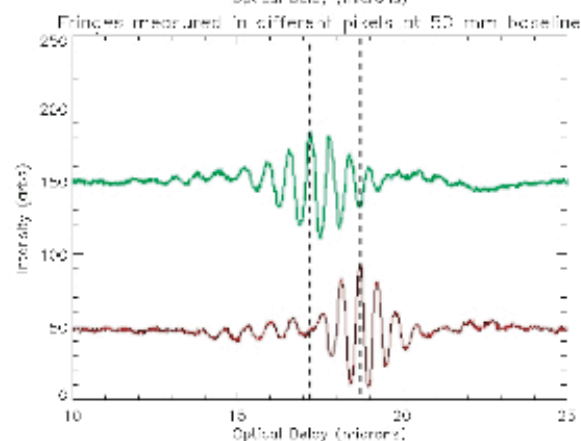
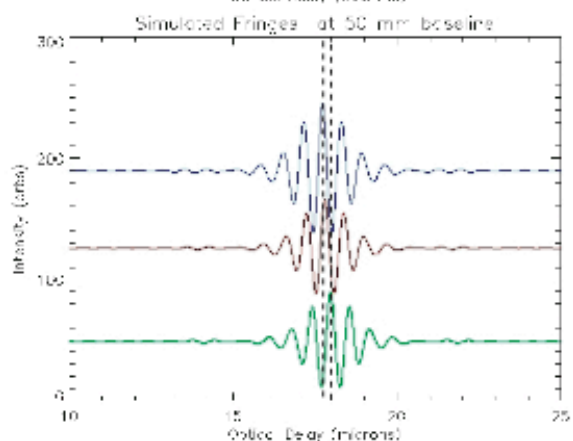
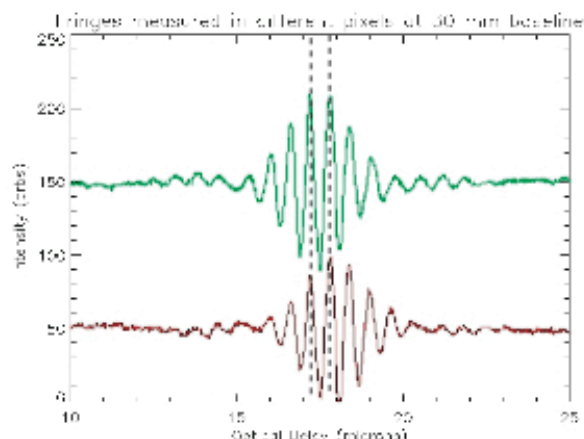
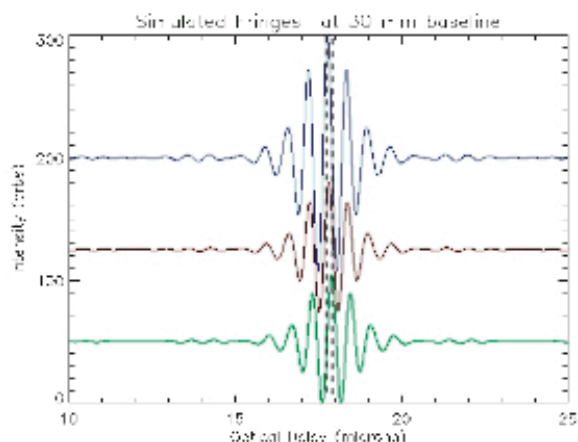
- Rinehart, et al. SPIE 5491-210, Glasgow 2004.
- Rinehart, et al. SPIE 5491-101, Glasgow 2004.
- Leisawitz, et al. 2002. Proc. SPIE 4852, 255.
- Rinehart, et al. 2002. Proc. SPIE 4852, 674.
- Leviton, et al. 2002. Proc. SPIE 4852, 827.

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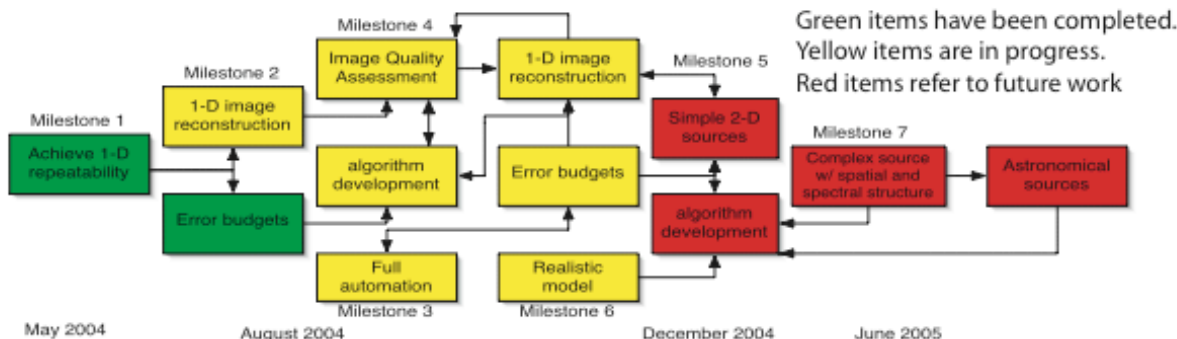
Table 1. Sources of Visibility Loss in WIIT

Source	Parameter Specification	Achieved	Uncertainty	Visibility Value
Alignment				
Field generated at Right Phase	> 95% overlap	97.5%	1.0%	0.975
Tip/Tilt at Exit Plane	< 0.0 arcsec	0.0 arcsec	0.000001 rad/rad	0.999
Optics				
Collimating Mirror	Surface roughness	15.75 nm	$\sqrt{2} \times 10^{-4}$	0.998
Beam splitter	Surface roughness	15 nm	$\sqrt{2} \times 10^{-4}$	0.998
Interferometer Mirrors	Surface roughness	10 nm	$\sqrt{2} \times 10^{-4}$	0.998
Coherent phase shift (Optics At Tilt)	Coherent phase shift	< 0.0001 rad	0.0001	0.999
Intensity Mod.	20 nm	0.0001	$\sqrt{2} \times 10^{-4}$	0.999
Phase Dispersion Error	< 0.0001 rad	0.0001	$\sqrt{2} \times 10^{-4}$	0.999
Total Predicted Visibility				0.998

These two tables show the error budgets for WIIT, including both visibility loss terms and uncertainty terms. At present, loss is dominated by the effects of imperfect optics, and uncertainty is dominated by the limitations of the current camera. Loss terms are not particularly worrisome, as they can be accounted for in post-processing, but uncertainty terms need to be addressed. We are acquiring a new camera which will greatly improve the noise characteristics of the system.

Table 2. Sources of Visibility Uncertainty in WIIT

Source	Parameter	Value	Uncertainty	Uncertainty (%)
Tip/Tilt Error				
Angular variation (< 1.0 arc)	1/12	0.0%	1/12	0.0%
Angular variation (< 1.0 arc)	1/12	0.0%	1/12	0.0%
Camera				
Tip/Tilt	0.01	0.0%	0.01	0.0%
Phase Coherence	10000	0.0%	10000	0.0%
Coherence (1/12 arc)	0.01	0.0%	0.01	0.0%
Dispersion				
Wavefront distortion	Measured			
Total Uncertainty in Measured Visibility				0.0%
Range Error				0.0%
Range Error				0.0%



Progress and Future work:

We have already made significant progress, and achieved the first of several important milestones in the development of WIIT. We expect to achieve several additional milestones by the end of 2004, and plan to be experimenting with algorithms and techniques within the next year. The eventual goal is to use WIIT to image complex sources such as a slide of the Hubble Deep Field. Double arrows in this figure indicate tasks which have mutual dependence.

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